# Prognostic Automated Contingency Management (ACM)

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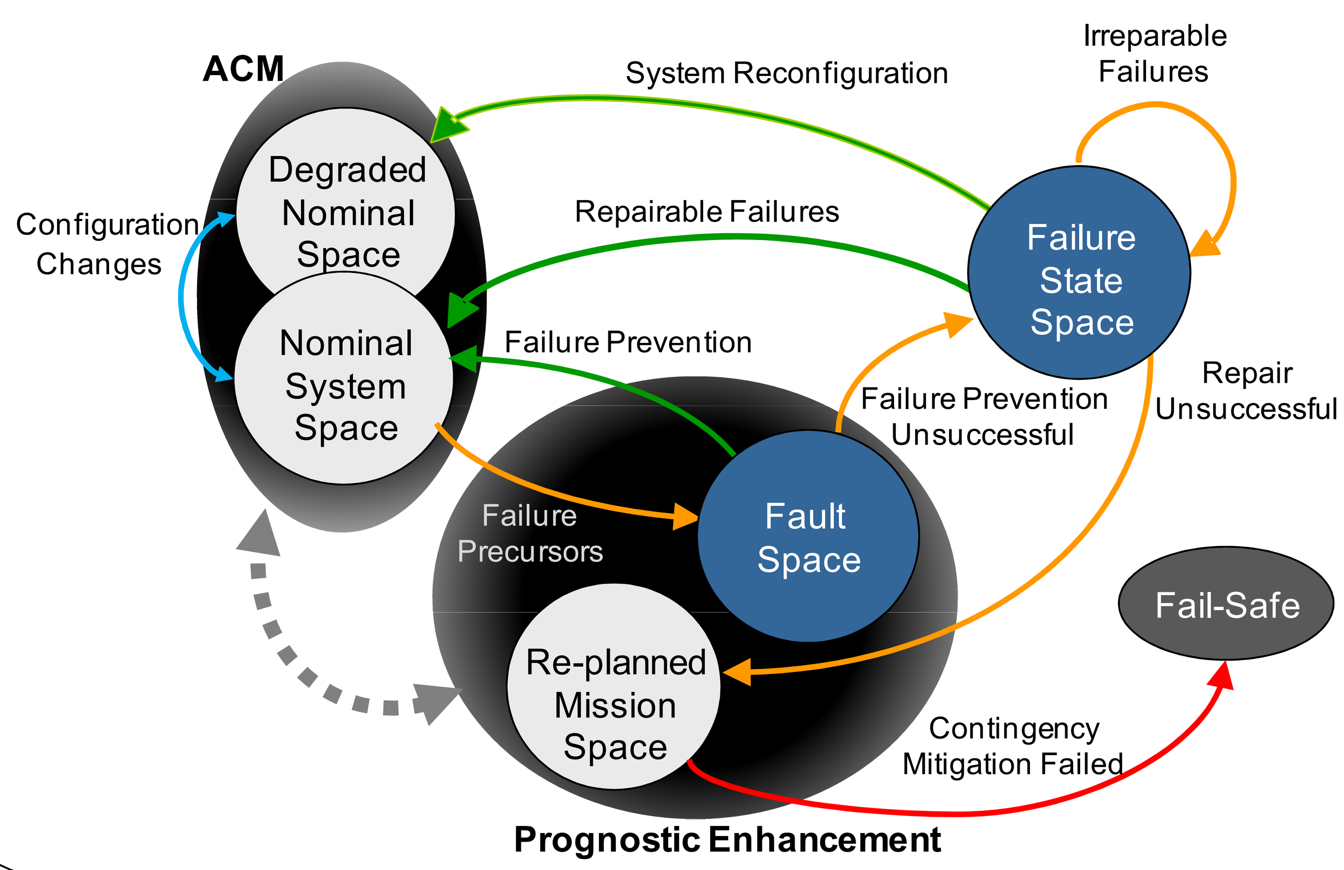
# Overview

## ACM Problem Statement

Given the current state of the system and Remaining Useful Life (RUL) estimates for deteriorating components, find the optimal action series that will bring the system to the desired state with a minimal cost and highest probability of success within predefined system constrains.




## Potential NASA/DoD Programs for ACM

**International Space Station (ISS)**
ACM for ISS power management system can help reduce the need of manual labor and improve maintainability and reliability of the ISS power systems.

**Unmanned Autonomous Vehicles (UAVs)**
Health management is a design-in feature for UAV's and faults are handled through ACM methods.

**Joint Strike Fighter (JSF)**
Fundamental to the success of JSF program are the development of on-line Prognostics and Health Management (PHM) and Autonomic Logistics for the aircraft systems.

**Space Shuttle Guidance Navigation & Control System (GN&C)**
An ACM integrated with prognostic information from sensor measurements will improve robustness and reliability to ensure shuttle safety.

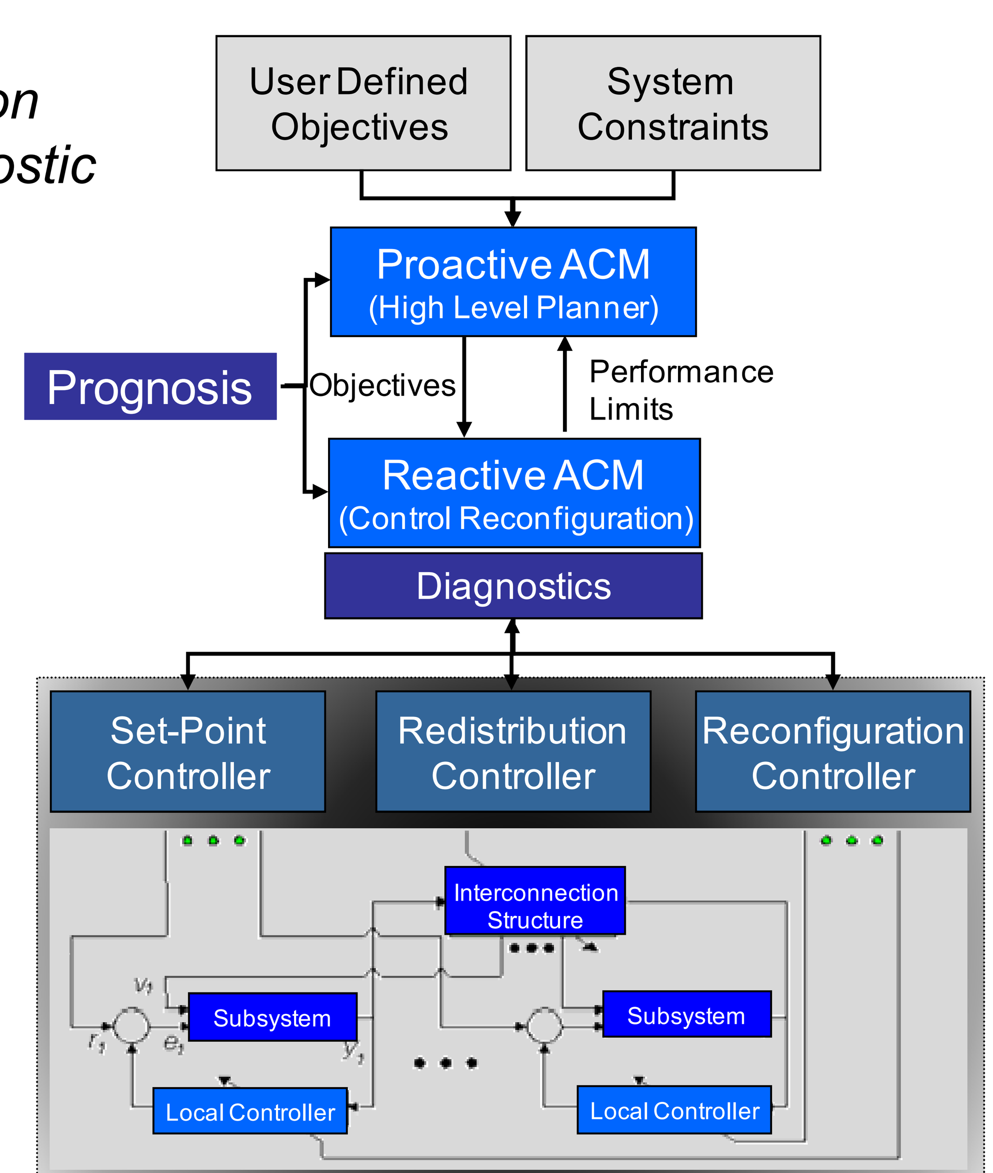
# Methodology

## System Architecture

Objective: *Demonstrate hierarchical decision making for reconfiguration based on prognostic information available to an ACM system.*

Approach: *Hierarchical Configuration*

- High level (mission) planning
  - Mission adaptation/re-planning
  - Ensure system stability and safety
- Mid level resource re-allocation
  - Restructure subsystems
  - Redistribute control authority
  - Ensure subsystem stability
- Low level (control) reconfiguration
  - Reconfigure set points
  - Ensure component dynamic stability




## Optimization based ACM

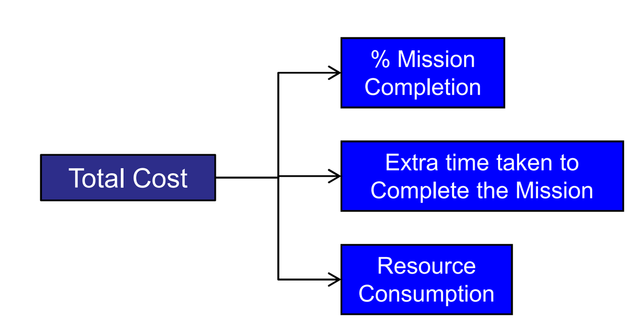
- High Level Mission Plan

$$J(M) = \max_M U(P_e, P_r, M, M_{com})$$ : maximize vehicle utility

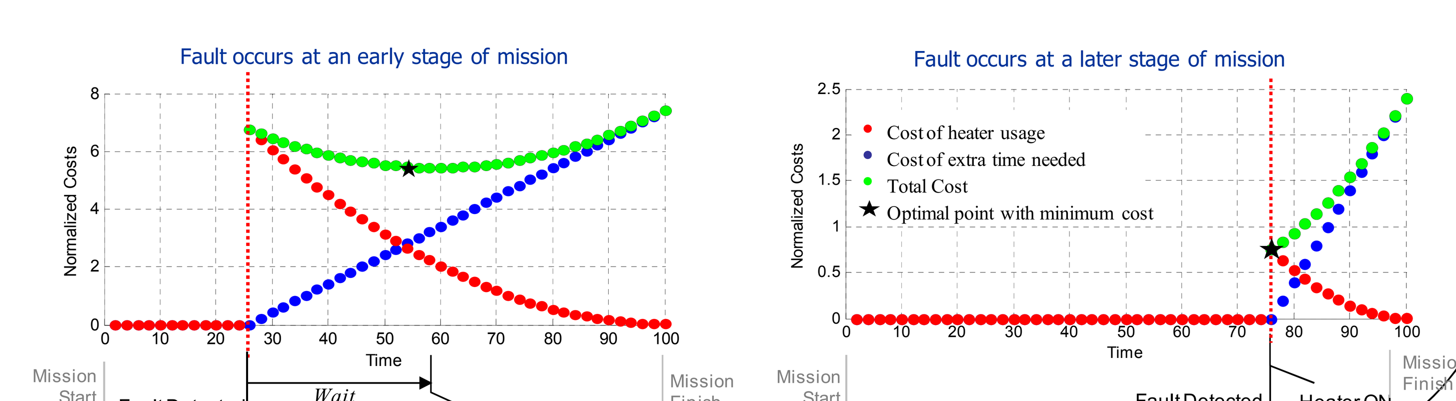
- Lower level Control Reconfiguration

$$J(R) = \max_R P_e(F_m, P_r, R, M)$$

$P_r$ - System prognostic information
$P_e$ - Closed loop performance
$M$ and $M_{com}$ - The mission objectives
$R$ - System restructuring indicators
$F_m$ - Fault mode

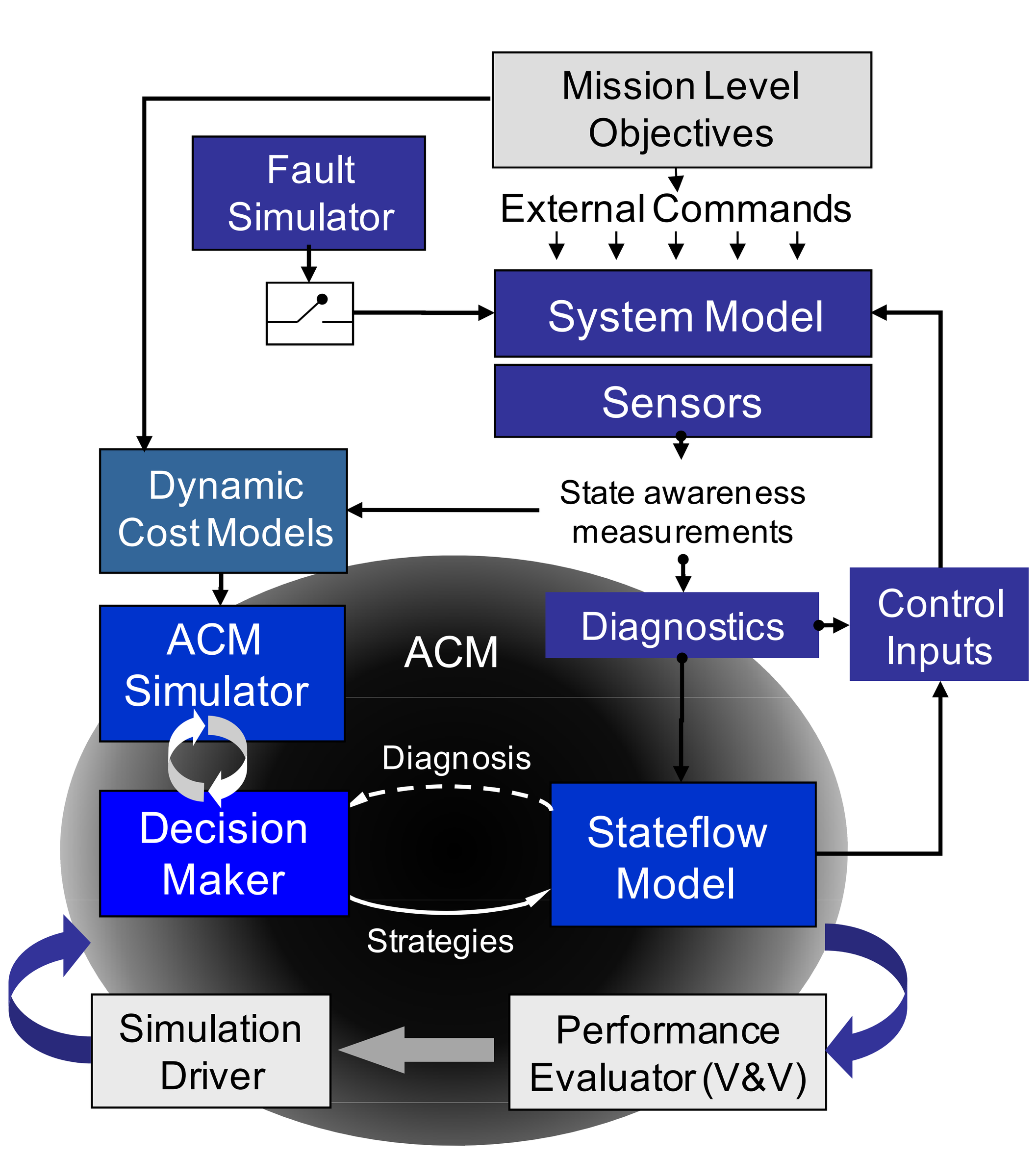



- Dynamic Cost Models
  - Requirements and resources modeled into quantitative costs
  - Costs change dynamically with mission completion stage




# Implementation

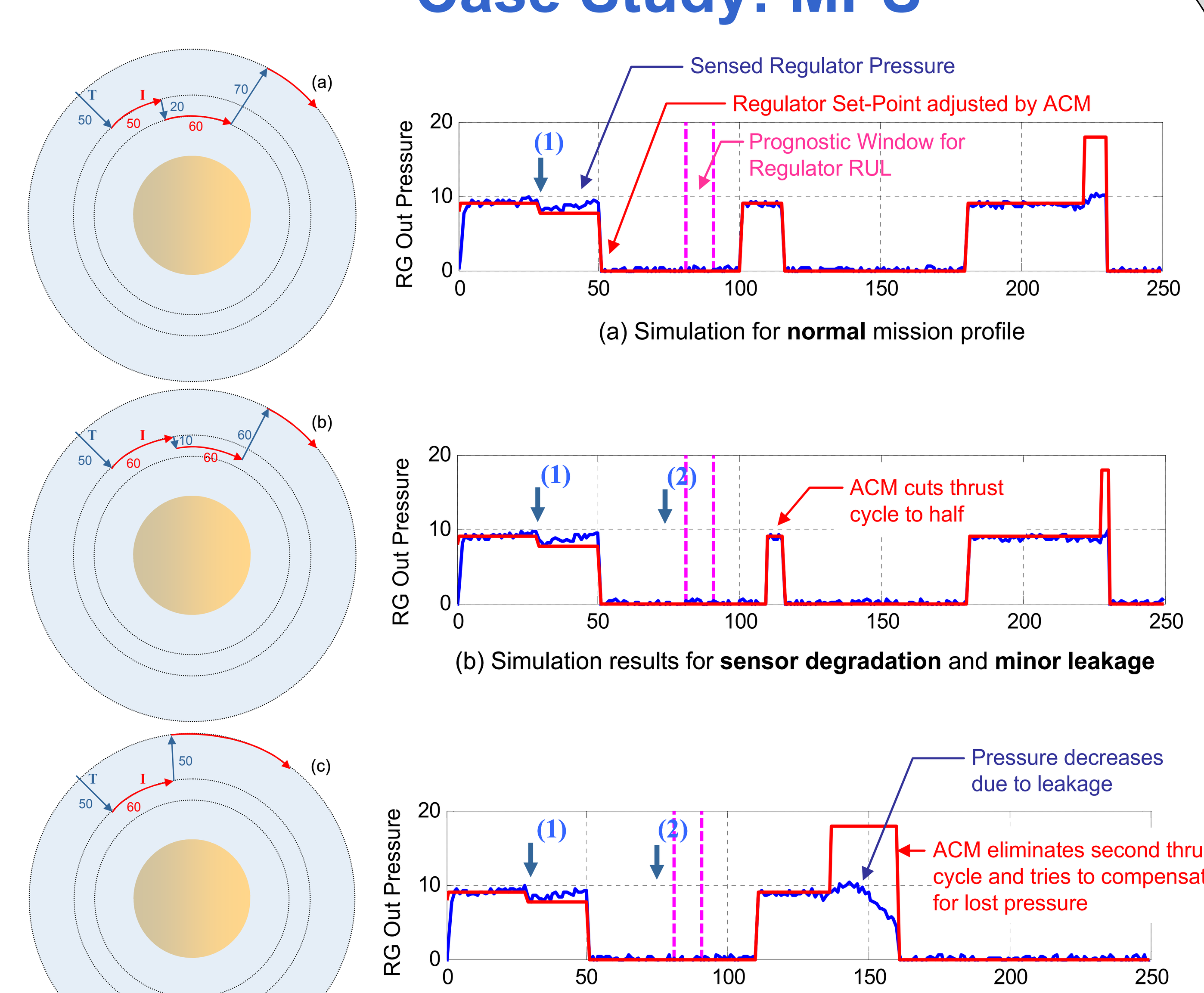
## ACM Design




## ACM Test bench

- System
  - Monopropellant Propulsion System (MPS)
  - Simulates various component failures
    - Regulator failure, heater stuck failures, valve stuck failures, sensor degradation, gas path leakage
- Scenario
  - Orbiter reconnaissance mission
  - ACM executes mission re-planning and system reconfiguration in the event of multiple simultaneous failures
  - Estimate the RUL of the failing components
    - Fault condition caused by corrosion in one of the pressure sensors of the regulator
  - ACM uses prognostic information for
    - Control authority reconfiguration
    - System level reconfiguration
    - Mission re-planning

## Case Study: MPS




(a) Simulation for **normal** mission profile

(b) Simulation results for **sensor degradation** and **minor leakage**

(c) Simulation results for **sensor degradation** and **severe leakage**

**Mission Profiles**



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